X-Ray and High Frequency in Medicine

By

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PREFACE

This volume is dedicated to my wife. It is due to her tireless energy that much of the material has been collected. During my busy life I have had very little time to devote to the collection and arrangement of facts that are necessary in a volume of this size. It was she who has made note of the various series of experiments that I have carried on in the last twelve years.

We have very little to offer that will be new to old operators, no startling discoveries have been made concerning the X-ray itself; since Roentgen's last paper, we have gained much knowledge concerning it, and it has made steady advances in its application, and the end is not yet.

In this book the reader will find my individual opinion, it contains my personality, as far as possible I have tried to give credit where credit is due, I have drawn freely from the literature of the age, and am under many obligations to the archives of the Roentgen Ray for its excellent translations of foreign papers. It appears the American physician will not support a journal upon this special subject, and the many valuable papers by American operators have appeared in many obscure medical journals, and have been lost to the great majority of physicians.

Some of the matter presented has been published in the Wisconsin Medical Recorder, and has been revised and brought up to date. I have purposely left out some well-known processes, involving the use of the Fluoroscope in diagnosis, as the Orthodiagraph and kindred methods, owing to its danger to both operator and patient.

I have spoken with the freedom of the class room and no one can read the volume without having much food for thought.

a fresh solution of developer, for a certain length of time, and the plate fixed, a new portion of the developer being used for each plate, and the temperature regulated at 60° Fahr.

By removing the covering from the tube, so its light escaped in the room, we found it required 10 seconds to get the same reduction of silver as before. A powerful beam of light from an iron electrode light, which was grounded after passing through the active field of the tube by shining upon a water pipe, required an exposure of 30 seconds to reduce the same amount of silver. Diffused daylight required 20 seconds' exposure, while a beam from the noonday sun, reflected by means of a mirror through the field and allowed to strike a grounded screen, required 180 seconds to reduce sufficient silver to compare with the original plates.

These experiments were repeated several times in order to eliminate errors, and verify our standards, and thy came close enough to determine the general law that the strength of the X-ray is varied in inverse proportion to the amount of ionization of the atmosphere after leaving a tube.

This discovery will be of far-reaching importance, and will explain many of the seeming inconsistencies of radiographic exposures, and presents a method of making radiographs with a minimum of exposure.

The ionization of the atmosphere allows the highly polarized X-ray an opportunity to escape. Its charge is neutralized and diverted from its course, and its energy absorbed by the surrounding atmosphere.

A strong beam of sunlight was allowed to pass through a pin-hole, making a narrow pencil of light pass through the active field of an X-ray tube in action, and a normal exposure given in order to see if any effect would be produced upon the plate. Its outlines were very strongly marked, and showed that the energy of the ray was absorbed by the light that passed through the field.

This discovery introduces a new factor in radiography, and may explain the efficiency of some of the different types of apparatus as used by different operators.

It seems clear from the foregoing that physicians must do their X-ray work in a darkroom, or at least one where the general intensity of light remains about the same.

There are many other unknown factors in the X-ray that will repay study, and when they are learned, it may be possible to devise a technique that may be used universally, with all types of apparatus.

No greater mistake can be made by any physician than to delude himself that he knows all about this radiation and attempt to despise it as a harmless agent. I have learned after twelve years' daily association with it that we know very little about it, and that it conceals a world of possibilities that are so far hidden from our knowledge. Its marvelous effects upon individual cases of disease, its utter lack of effect upon apparently similar cases, cannot be explained upon any other grounds than ignorance of the operator. He is successful because of things he does not understand, and fails in his work for the same reason.

GENERATORS.

To obtain a high potential current for X-ray work, we must have some form of generator, especially calculated for this purpose, and we have found that the work can be done in many ways, and we must classify them as follows:

Open Transformer or X-ray Coil.
Closed Transformer.
Special High Frequency.
Static Machines.
Storage Batteries.

The Open Transformer has been the instrument used in most laboratories up to the present time, and may be preferred for some time in the future, although the progresss now being made with the closed transformers and the High Frequency may at any time supplant them. As a general rule, the principles of the Ruhmkorff coils are followed with some modifications of the Richie system of winding. Ruhmkorff wound the secondaries of his coils straight across from one side to the other, running the wire through shellac as an insulating medium. This was found to be a fatal weakness when we began to use them for high potential work, owing to the amount of moisture retained by the alcohol in the shellac. No method could prevent both moisture and oil being included in construction, so that in order to keep the insulating properties within reasonable limits, the bobbin system of winding devised by Richie has superseded the old methods.

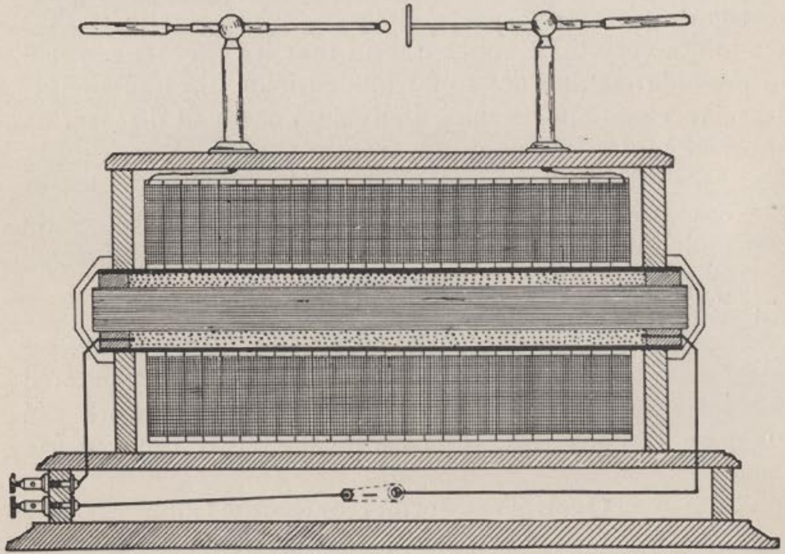

FIG. XV. OPEN TRANSFORMER OR SO-CALLED X-RAY COIL

The Open Transformer is constructed by taking a given quantity of soft annealed iron wire of a known quality, and by compressing it into a bundle, from one to three turns of insulated wire is wound around the iron and connected either in series or parallel, or in certain coils so it can be used both ways, if desired. This is called the **Core** or **primary** of the coil.

The Core—We use wire of from No. 8 to No. 14 B. & S. gauge for our primary windings, depending upon the construction of our coil and the output desired. During the last few years, the primary has been constructed in such a manner that a tap has been taken off at regular places in the primary windings in order to vary the **inductance** of the coil. In this manner, we can get just enough electro-motive force to excite any tube we desire, and work it at its maximum capacity, without getting a superfluous amount of voltage as a disturbing factor. This is an ideal manner of construction, but probably few operators have discovered its desirable qualities as yet, owing to a general lack of knowledge upon this subject, and the farther fact that the majority of X-ray men will persist in using too high a tube.

Penetration and Inductance—If we learn just what penetration we get upon a certain button of our primary coil, all we have to do to obtain this penetration is to connect up our coil this way, and reduce our tube to the desired vacuum, and in this way we eliminate the matter of guesswork, and work with precision. By this method, if our tube goes to a higher resistance, it simply will not give off X-rays with this voltage until it is reduced again.

Shunt Circuit—For those operators who use a shunt circuit tube with a regulator, it can be maintained at this resistance, with no trouble, for hours. By doing away with our extra voltage, our tube balances well, and no flickering is noticed in its operation: moreover, we can crowd a tremendous amount of current through it without much surface induction.

Insulation of Core—After a primary is wound, it is boiled in either a wax or insulating compound, in order to prevent the possibility of an arc forming between the layers. For a standard 12-inch coil the size of the finished primary is 2⅞ inches in diameter.

We wind our secondary in bobbin form, and in several different systems. The so-called "pancake section" effected by the manufacturers of wax coils, and the bobbin section—usually one inch wide—as used by those manufacturers who use soft insulation, as vaseline. These bobbins or spools, after being wound, are saturated with an insulating compound and assembled in a suitable box, and upon a tube of mica and shellac, after the coil is put together, with all joints soldered, the box is filled with wax or vaseline, as may be preferred, and the primary placed into the tube. It is made in this manner to permit its removal for repairs if found necessary from accident.

Skiagraphic Coil—For skiagraphic work, a 12-inch coil is amply sufficient for all practical purposes, and if properly made, will make a plate in as short a time as the larger ones.

A well made coil wound in pancake sections, and insulated in Beeswax is in every way the best coil, as it is almost unknown for one of them to break down under strain, while the winding being almost solid wire with only a thin layer of cellulose paper waxed between the sections, makes it impossible to include either air or moisture in their manufacture.

The coils made with vaseline are peculiarly subjected to a breakdown, owing to the acids or alkalies frequently found in cheap vaseline, eroding the wire.

Repair of Coils—The apparent advantage claimed by each maker of one or the other being easily repaired if an accident happens, loses force when we know that either one can be repaired without much trouble, if necessary.

The Closed Transformer—In this type of apparatus, we have one with great latent possibilities in it, and it is unquestionably the coming apparatus. The fact that it is a low period machine on the commercial alternating current and for this reason requiring a longer exposure for a skiagraph, has worked against it heretofore.

Polyphase Currents—It is easily conceivable, however, that it will occur to our makers that the period can easily be increased by using a polyphase current which is available in many towns throughout the country. In this way we can send wave after wave through our primary and ground the back wave. This will increase our periods to such an extent as to make it a close competitor to any open transformer upon the market today, and one that will exceed it in power.

By this method of construction, we would have no more inverse current than with the former coil. I have constructed experimental apparatus along this line, in which a satisfactory skiagraph was made of the pelvis in 1-10 of a second, with a tube distance of four feet. A curious fact was noted with my transformers that I could force 32 milliamperes of current through a tube that would absorb only four with a powerful open transformer. Before I stumbled upon this fact, the target of three beautiful tubes was melted. With a period of 120, I was able to make a good Hip Joint skiagraph in 20 seconds, so that even with the drawbacks of a low period commercial current, it exceeds the great majority of open transformers upon the market today.

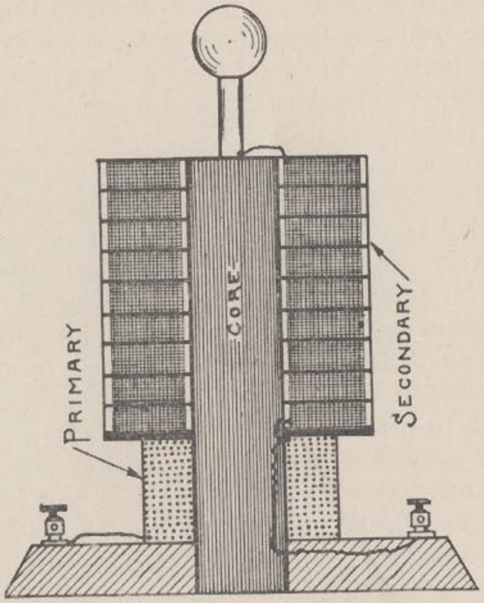

FIG. XVI. CLOSED TRANSFORMER

Alternating Current and Villard Tube—Where we use the alternating commercial current of 60 cycles, we have to use a Villard valve tube in the line to block all inverse current, which would otherwise ruin our tube by depositing platinum upon its walls. This tube allows a current to go through it one way, but blocks a current going in the opposite direction. The main objection to these contrivances in the past has been their small capacity, and their tendency to increase in vacuum. This has now been overcome by improved construction, and the attachment of a regulator upon them.

This type would have the immense advantage of being attachable to any alternating current without an interrupter, and could be used with the direct current with an electrolytic interrupter. They would be small in size very powerful, and have nothing to get out of order.

High Frequency Coil, Special—It has been known since the discovery of the X-ray that the High frequency current is available for X-ray work where the principle was utilized in a proper manner. Mr. Kinrade produced the first practical type, unfortunately of too small capacity for the commercial work expected of it, and for a time it fell in disrepute, until Dr. Strong applied the principle in a different way, and again increased the capacity, but still short of what was expected from an apparatus of this kind.

Portable Highfrequency Coil—During the last year, much thought has been given to the matter, and several small portable types have been evolved that satisfactorily settle the question of a small compact portable apparatus for this work. I have had the pleasure of testing a portable machine made by Mr. J. B. Wantz, the talented Electrical Engineer of the Victor Electric Co., and succeeded in getting a remarkable series of skiagraphs of all parts of the body that compared favorably with anything that can be gotten from a larger machine, and it is no exaggeration to say that as good work can be done upon it as can be done by the larger types, with about 60 percent more exposure—a matter of small consideration when we come to think of the difference in cost, and its portability.

High Frequency Flame—Mr. Wantz has succeeded in developing a larger type that is a strong competitor to any upon the market today, and the end is not yet. There is no theoretical limit which confines these coils to any known size, as Nikla Tesla has demonstrated that a flame 68 feet can be drawn from a transformer of this type.

High Frequency Insulation—The principal difficulty in this type of machine is its insulation, as the current will pass through four inches of solid glass, and in fact, we have no known form of insulating compound that can confine this current to a conductor, and their construction is possible only by carefully calculating the self induction of each wire and winding them in such a manner that each turn is insulated by its own self induction—a problem for the finished electrician alone.

Leakage of Current—It is a curious thing to observe turns of wire running beside each other, charged with a potential sufficient to spark twice their distance, and no leakage taking place. One serious objection to this type of apparatus is the enormous leakage from the conducting wires, each wire having a beautiful brush discharge, owing to the ionization of the surrounding atmosphere. This is not vital, owing to the immense output of this type of coil.

Inverse Current—Second, having an inverse current, we require special tubes to reflect off the ray given off from the period we do not use. This is the most serious difficulty we have with this coil, as it prevents a sharp line of demarcation in the X-ray tube, and makes its regulation a difficult matter, to say nothing of an active field being thrown off in the possible direction of the operator. The tube manufacturer has as yet not solved the problem of a High Frequency X-ray tube, and it will probably have to be constructed with lead glass with a Bohemian glass window opposite the active field.

Static Machines—We have three distinct types, the Winshurst, the Holtz, and the Toepler-Holtz. These machines work upon several different principles and have been a source of mystery to Physicians as to why they generate a current.

If we will go back a ways and study **polarity,** we will soon find the origin of the initial current in these machines. We learned that by insulating a conductor and applying heat to one part of it, that we created an unequal molecular motion, and the current not being able to escape to the earth, the electro-motive force gradually grows greater until a spark passes and the current escapes.

Polarity in Static Machines—This is where we get our polarity in a static machine. We place upon varnished glass plates, metal sectors, with a raised center, and bring a brush to bear upon the center, while we revolve the plate. The succession of blows from the brush transmits energy, and the temperature rises in the raised portion of the sector. This gives us an unequal motion in the metal and polarity, is established. When we have succeeded in getting polarity, another principle is brought into play, called **Induction.** As we have learned before, wherever we polarized a conductor, a transfer of the electrical charge of the ether takes place, giving rise to a disturbance that passes out into space at a distance, depending upon the electro-motive force of the initial charge. We find that by charging the sector of a static machine and discharging and reversing its polarity each revolution, that a series of electro-magnetic waves are set up in the ether, the positive absorbing the negative charge of the ether, and the negative parting with its charge to the surrounding medium, so that we can conceive of a rotating static machine plate as being subjected to a bombardment of the minute electric charges of the ether upon one side, attracting the particles with enormous velocity, owing to the high electro-motive force, and giving out a charge upon reversal of polarity to the ether particles. In this way our current output is rapidly increased.

Electro-Motive Force of Static Machines—The diameter of the plates and the speed of rotation determines the electro-motive force, this increasing in inverse proportion to the square of the speed.

Ampere Output of Static Machines—The current output depends upon the diameter of the plates, and their number, and increases in inverse proportion to the speed and not in direct proportion, as has been asserted by some authors. In other words, if a machine running, say 500 revolutions per minute, gives us ½ a milliampere of current, 1000 revolutions a minute will not give us one milliampere, but only a 25 percent increase in current.

The only way to increase our current output, is to add more plates, or increase their diameter, the latter method not being wholly satisfactory, owing to the increase of electro-motive force as well.

Static Machine as a Generator—As a generator of the X-ray, the static machine has not been found wholly satisfactory, owing to various reasons. For instance, the large size of a machine required to do laboratory work, makes it unwieldy and cumbersome, while the induction given off from the machine is very distasteful to many patients, and occasionally gives rise to the so-called Induction burns.

Moisture and Static Machines—Second, they are not reliable, owing to their susceptibility to the amount of vapor in suspension in the atmosphere, necessitating the use of various chemicals to absorb the moisture within the case. There are many methods of overcoming this problem, and while they all accomplish it within certain limits, they all have certain drawbacks that render their use undesirable.

Calcium Chloride C. P. Dryer—This chemical dryer is usually recommended by the manufacturers as the ideal salt to use for this purpose, and as far as the moisture problem is concerned, it accomplishes its work well—still the fine particles of this salt are polarized and attach themselves to the plates, and, absorbing moisture, gradually cause an immense leakage of current to take place,